UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

EFFECT OF MICROWAVE CURING ON LAMINATE COMPOSITES PERFORMANCE

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ABSTRACT

At present, composites material becomes common material in industries such as aerospace, aeronautical, automobile and also sports. The high specific stiffness and also high specific weight makes it ideal for the panel ans structure parts of the product in that particular industries. This show the growth of composites manufacturing industries thus high rate of production. These composites material is costly compared to other metal due to its complicated and lengthy fabrication process. Also, due to its uniquely curing process, it requires time for curing and also heat in order to help the curing makes the composites material to rise in price. Therefore, microwave curing process is studied in order to shorten the curig process without ignoring the performance of the material.

ABSTRAK

Pada masa ini, bahan komposit menjadi bahan biasa dalam industri seperti aeroangkasa, penerbangan, kenderaan dan juga sukan. Ketegaran yang tinggi dan juga kekuatan yang tinggi menjadikan ia sesuai untuk bahagian-bahagian struktur panel dan produk dalam industri-industri yang tertentu. Ini menunjukkan pertumbuhan industri pembuatan komposit yang tinggi. Bahan komposit adalah mahal berbanding dengan logam lain kerana proses fabrikasi rumit dan panjang . Antara sebab lain adalah disebabkan oleh proses unik pengerasan, ia memerlukan masa dan juga haba untuk membantu pengerasan dan justeru menjadikan bahan komposit meningkat dalam harga. Oleh itu, proses pengawetan gelombang mikro dikaji untuk memendekkan proses pengerasan tanpa mengabaikan prestasi bahan

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Thought Course

Signature	:	....
Name	:	....
Date	:	....

DECLARATION

I declare that this thesis entitled “Effect of Microwave Curing on Laminate Composites Performance” is the result of my own research except as cited in the references. The thesis has not been accepted for any Master and is not concurrently submitted in candidature of any other Master.

Signature : ....

Name : ....

Date : ....

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CHAPTER 1

INTRODUCTION

1.1 Background

In making composite laminates, curing process is a must as it needs to cure or harden the soft resin to become rigid and thus hold the fiber together. There are several methods of curing available until now. The simplest curing proses are to allow the resin cure at room temperature. Curing proses time can be shortened by applying heat to the laminates. These techniques have been done in several ways by using conventional oven and autoclave. Also, they are some unique technique which uses UV light to apply the heat to the laminates.

There are widely high performance thermoset parts of laminates need heat and pressure to cure which require the autoclave. Autoclaves are normally expensive to buy and expensive to operate and maintain. Usually Manufacturers that are having autoclaves cure many parts at the same time. Autoclaves use computer system to monitor and control temperature and pressure. This allows remote supervision of the process of curing.

When heat is added to the curing system, the temperature of the part is ramped up in small increments and maintained at cure level at a specific period of the resin recipe, and then there is ramped down to room temperature. This normal curing process cycle is to make sure there is no warp caused by uneven contraction and expansion.

With various techniques nowadays, there are possibilities to improve the curingtechnique by heat application. Hence a lot of studies need to be taken to shorten the period of curing.

1.2 Problem statement

Composites Laminates has widely used currently in industries and their properties is appreciated amongst engineers as it is high specific stiffness and high specific strength. Curing is one of the main process of fabricating the composites laminates as it is a nature process to let the matrix to harden as it will hold the reinforcement together and makes the material become stronger and stiffer. Normal practice of curing involves long period of time. For example room temperature curing period is upto 24 hours of curing whereas high temperature curing is up to 2 hours. The normal practice of high temperature curing is using the conventional heater as a heat supply and therefore it has to take some time to gain the temperature. Microwave heating is one of the alternative to supply rapid heating as it does not need any convection or conduction process to heat up the material. Hence this study will show the effects of microwave curing to the composites of laminates and the performance of the laminates is measured.

1.3 Objective

The aim of this study is to:

- Study the optimized parameter of microwave heating into the wet lay-up process.
- Compare the overall mechanical properties of the fabricated composites.

1.4 Scope

In this study, the relationship between the microwave parameter of power usage and the heating time is developed by the response of mechanical properties of fabricated composites strength and modulus of elasticity.

1.5 Significance of Study

At the end of this research, the results is beneficial to any manufacturer of composites especially composites factory in the industries as they may reduce the process time and increase the productivity by the reduction of cost

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Advanced composites in general have a high specific stiffness and strengths compared to metals which give the advantage of industries which need a high stiffness and strength material that having a reasonable low weight. This is good to industries such as aerospace industries, automotive industries for having reinforced fiber composites in their product as a structure. This type of advance material has been of considerable material research of fabrication method in the past three decades. Though, many of the researchers have been study in order to fabricate on high performance material of advance composite with excellent properties of mechanical, physical, and chemical. Hence, there is little emphasis study on the cycle time of the fabrication process. This is very important to the manufacturer of the composites to reduce the cycle time of the process as waiting time is one of the wastes in the theory of 7 waste management. Normal practice of composites curing is letting the material to cure on normal room temperature, others are using mechanical heater such as oven and autoclave to give some heat to the material as it may reduce the time of curing. However, there is another option of technology that can support the composites curing and thus reducing the cycle time of curing process which is microwave heating.

Microwave heating is an alternative of the conventional oven or autoclave which uses mechanical heater to heat the air surrounding the composites material. This type of heating system reduces as much as 90% of the curing time compare to room temperature curing. However, with the advantage of microwave heating, it may reduce the curing time generally by 90% of the normal conventional heating system. Microwave radiation produce heat within the material

2.2 Glass Fiber

Glass fiber was created in 19322 by Russel Games Slayter of Owen-Corning. The material was used as a thermal insulation in buildings. After many years, researcher found the advantage of the glass fiber as a reinforce agent for a polymer and for becoming a structure for certain application. Glass fiber has comparable mechanical properties to other fibers such as carbon fibers, and armid fiber. The Glass fiber do not have the stentgh as carbon fiber and aramid fiber, but due to its low cost, and significantly less brittle when used in composites, that is why the glass fiber becomes the popular choice amongst manufacturer as a reinforced agent for their composites. The glass fiber normally inforced with polymer and usual name of the material is glass fiber reinforced polymer (GFRP) or also known just as “fiberglass”.

2.3 Fiber Formation

Glass fiber is formed by the thin strands which based on silica with other formulation of glass extruded into fibers which have small diameter to suits textile processing. This techniques of heating and also drawing the glass into fine fibers is called millennia. Other than this glass fabric, there are also called staple process which formed the glass fiber into cluster, which consist of short length of fiber.

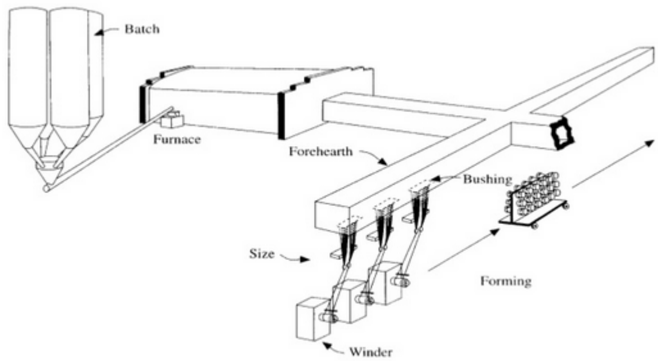

Figure 2.1 Glass Fiber Manufacturing Process

Figure above shows the manufacturing process of the fiber formation itself. This process is prior the process of the manufacturing of composites laminates as the manufacturing of composites laminates uses the product of glass fiber in a fabric form whether it is woven, unidirectional or mat form.

Figure 2.2 Glass Fiber Woven

Figure 3.2 shows a piece fabric of glass fiber woven type. This type of glass fiber is widely used in the industry such as water tank and automobile bodykit industries. The cost of this type of glass fiber fabric is amogst the cheapest among other type of advance composites.

Normally used types of glass fiber is E-glass fiberglass. This type of fiberglass is alumino-borosilicate glass which contain less than 1% w/w alkali oxides, mostly used for reinforced plastics. Other types of fiberglass that are also used is A-glass (Alkali-lime glass with little or no boron oxide), E-CR-glass (Electrical/Chemical Resistance; alumino-lime silicate with less than 1% w/w alkali oxides, with high acid resistance), R-glass (alumino silicate glass without MgO and CaO with high mechanical requirements as reinforcement), S-glass (alumino silicate glass without CaO but with high MgO content with high tensile strength), C-glass (alkali-lime glass with high boron oxide content, used for glass staple fibers and insulation), and D-glass (borosilicate glass, named for its low Dielectric constant)

E-glass ("E" because of initial **e**lectrical application), is free from alkali, and it is the first glass formulation used for the continuous filament formation. It is now makes up most of the fiberglass production in the world, and the E-glass also is the single largest consumer of boron minerals globally. It is prone to chloride ion attack and it is not a good choice for marine applications.

2.4 Mechanical Properties

The mechanical strength of glass is usually tested and reported for "virgin" or pristine fibers which that have just been manufactured. The more the freshest and thinnest fibers are the strongest because the thinner fibers having the most ductile properties.Due to glass fiber has an amorphous structure; the material will have the same properties along the fiber and across the fiber. Different with carbon fiber, glassfiber can undergo more elongation before it breaks. There is a relationship between bending diameter of the filament and the filament diameter.

2.5 Glass-reinforced plastic (fiberglass)

Glass fiber reinforced plastic (GFRP) is a fiber reincforced plastic or composite material made of a plastic reinforced by fine glass fibers.The composite material is commonly called as fiberglass. The glass can be in the form of a woven fabric or a chopped strand mat (CSM). (Erhard, G. and Thompson, M., 2006)

As per any other composites, for example the most popular compsites which is concrete, there are two materials involve and work together. One material to withstand the load (reinforcement), and one material works as binder (matrix). Same as the GFRP, the plastic resins work as a binder and and the glass fiber works as reinforcement of the material. (Barbero, E.J., 2010)

Figure 2.3 Hand Lay-up Process

Figure above shows the process of hand lay-up for which every layer of fabric is put together on top of the mould which shaped the final product.

2.6 Curing

2.6.1 Conventional Oven

Conventional oven is widely used in composites laminates preparation after room temperature curing as it uses basic principal putting addition heat to the laminates in order to fasten the curing process. The heating system uses electric resistor as electrical current pass through the resistor, the energy will be converted from electrical energy to heat. Figure 3.4 below shows the example of conventional curing oven for composites industries.

Figure 2.4: Conventional Curing Oven

2.6.2 Autoclave

Figure 2.5 Outoclave

Figure above shows three different size of autoclave. Autoclave is basically having the same principal as conventional oven, but with the addition of pressure. With extra pressure, it helps to compress the laminates that want to cured and helps to take out any air bubles (void). Curing the composites with autoclave will enhance the physical and menchanical properties laminates.

2.7 Dielectric Heating

Dielectric Heating which is also known as electronic heating RF (radio frequency) heating, and also high frequency heating. It is the process which a high frequency alternaging electric field, or radio wave or microwave heats a dielectric material. At the higher frequencies, the heating happened is caused by molecular dipole rotation within the dielectric.

2.8 Microwave Heating

Microwave heating, as compared to radio frequency (RF) heating, is a sub-category of dielectric heating at frequencies above 100 MHz, where an electromagnetic wave can be expelled from a small dimension of emitter and directed through space to the target. Current microwave oven make use of the electromagnetic waves with electric fields of higher frequency and shorter wavelength than RF heaters. Normal domestic microwave oven operates at 2.45 GHz, but 915 MHz ovens also exist. Thus, this means that the wavelengths working in microwave heating are 10^{-1} to 10 cm. This provides for highly efficient, but less penetrative, dielectric heating. (Michael P áMingos, D., 1991).